



Objectives for Human Missions to NEOs

PLANETARY DEFENSE

Presented by: Lindley Johnson

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We find there can be significant synergy between the PD and Human Missions in Search Survey and Characterization by Precursor Missions.

This may be the most important benefit to PD.



- **Testing various PD capabilities**
 - Human could make test equipment work
 - Able to reduce risk of failure; risk mitigation
 - Lessons learned from Hubble (i.e., improvisation)
 - Able to synthesize and adapt from data
- **Confidence builder in campaign of operations**
- **Increase confidence in impact effects (Beta) by test**
- **Techniques that require surface attachment**
 - Precise anchoring/placement of disruptors
 - Selection of attachment/landing points

Planetary Defense: Insights, con't.



- **Autonomous terrain-relative navigation (grav tractor; lander); Test rapid grav field modeling**
- **Public Awareness**
 - Increase public visibility/understanding so humans on Earth can follow
 - Sustained human interest during NEO mission (shorter duration; more visibility)
- **International Participation**
 - Build confidence in international collaboration ala ISS

Planetary Defense: Capabilities & Tools – Rapid Impulse



- Surface Explosive
 - Attachment techniques
 - Small Explosive Devices
- Subsurface Explosive
 - Penetrator
 - Penetrator gun
 - Seismometers
 - Dig a Hole
 - Drilling Tool
 - Small Explosive Devices

Planetary Defense: Capabilities & Tools – Rapid Impulse, con't.



- Kinetic Energy Impact
 - Use Hypervelocity Gun
 - Measure Beta Factor
 - Variation
 - Seismic
 - Measurements
 - Measure
 - Mass
- Nuclear Standoff
 - Measure Surface Characteristics
 - Regolith composition
 - Sample Return
 - Measure Mass

Planetary Defense: Capabilities & Tools – Slow Push



- Ablation Techniques
 - Small Laser
 - Mirror for focused sunlight
 - Measure Mass and Velocity of ejecta
- Enhanced Natural Effects
 - Measure Albedo prior to arrival
 - Change Albedo @ end of mission
 - Track object after mission

Planetary Defense: Capabilities & Tools – Slow Push, con't.



- Gravity Tractor
 - Precision transponder (placed @ precise location visible from Earth)
 - Precision lidar/radar for s/c to asteroid distance
 - s/c with autonomous nav and thrusting
- Attached Thruster
 - Large solar sail
 - Attachment/anchoring techniques
 - Attitude Control Sensors
 - Observe dust effects
- Mass Driver
 - Attachment techniques
 - Drilling techniques

PD Concept of Operations

